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Dynamic and Static Fracture Toughness Measurement

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ABSTRACT

Two unique measurement systems for generating toughness parameters will be detailed during this presentation. The first is an ACPD Crack measurement system which has been integrated into an instrumented impact test system. This system can be utilized to generate dynamic J-resistance curve information. The second system is a specialized differential extensometer which can be used to accurately measure axial strain in tension specimens experiencing plastic necking. This system can be used for experimentally generating the data necessary for conducting a strain energy density analysis of a material system. This device may alternatively be used to characterize the partitioning of strain across a weldment in uniaxial tension.

OVERVIEW

DYNAMIC J-R CURVE

- THE PROJECT OBJECTIVE WAS TO DEVELOP AN INTEGRATED HARDWARE/SOFTWARE SYSTEM CAPABLE OF GENERATING DYNAMIC J-RESISTANCE TOUGHNESS INFORMATION
- DETAIL THE INTEGRATION OF AN ACPD CRACK MONITORING HARDWARE INTO AN INSTRUMENTED IMPACT TEST SYSTEM
- EVALUATE THE ACCURACY OF THE SYSTEM

DIFFERENTIAL AXIAL STRAIN

- THE PROJECT OBJECTIVE WAS TO DESIGN AND DEVELOP A SYSTEM CAPABLE OF MONITORING DIFFERENTIAL AXIAL STRAIN AT MULTIPLE POINTS OVER THE GAUGE LENGTH OF A TENSION SPECIMEN
- DETAIL THE DESIGN OF THE SYSTEM DEVELOPED TO MEET THE OBJECTIVES
- EVALUATE THE ACCURACY OF THE SYSTEM

TECHNIQUES FOR GENERATING J-R CURVE DATA

FORCE

- NORMALLY GENERATED DIRECTLY FROM A CALIBRATED FORCE TRANSDUCER

DISPLACEMENT

- LINEAR VARIABLE DISPLACEMENT TRANSDUCERS
- RESISTIVE ELEMENTS
- OPTICAL METHODS
- INDIRECT METHODS

CRACK EXTENSION

- MULTI SPECIMEN
- UNLOADING COMPLIANCE
- ELECTRICAL RESISTANCE
- NORMALIZATION (KEY CURVE TECHNIQUES)
- POTENTIAL DIFFERENCE METHODS

SYSTEM FORCE- DISPLACEMENT MEASUREMENT

FORCE - DIRECT
DISPLACEMENT - INDIRECT

$$m\int V\,dV + mg\int dh - \int P_a V_a\,dt = 0$$

$$V_o = \sqrt{2gh_o}$$

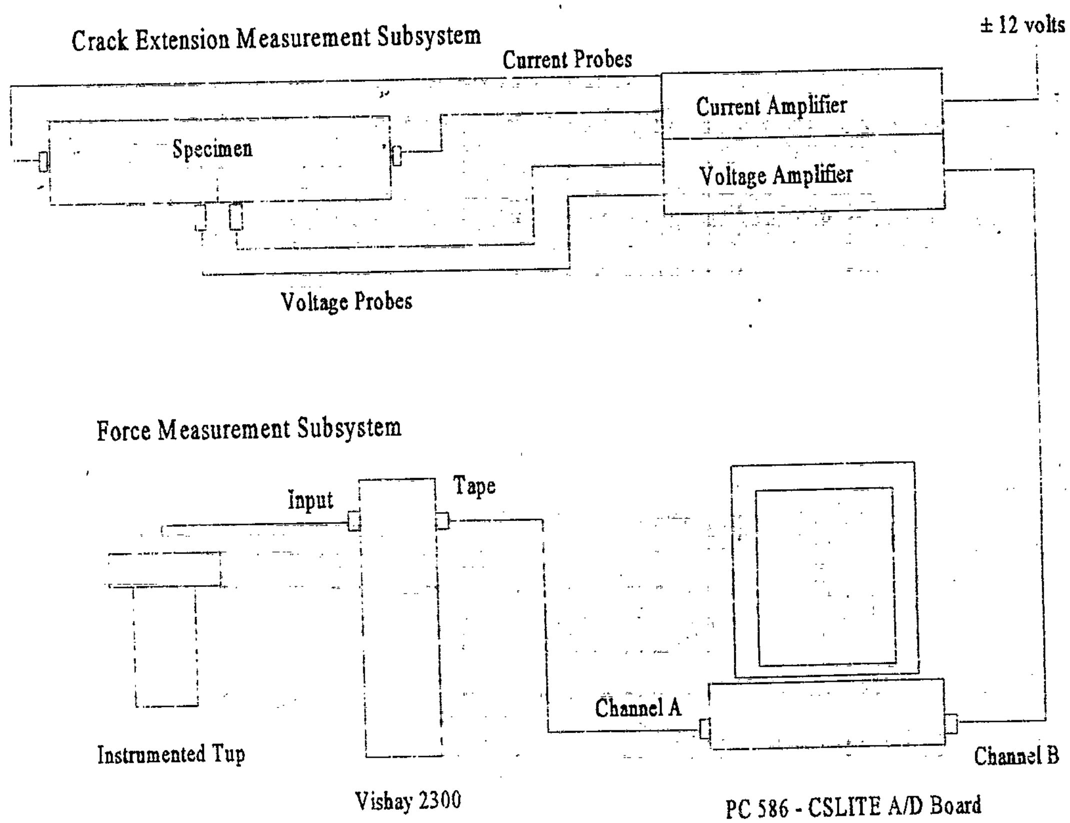
SYSTEM CRACK EXTENSION MEASUREMENT

DIRECT ACPD

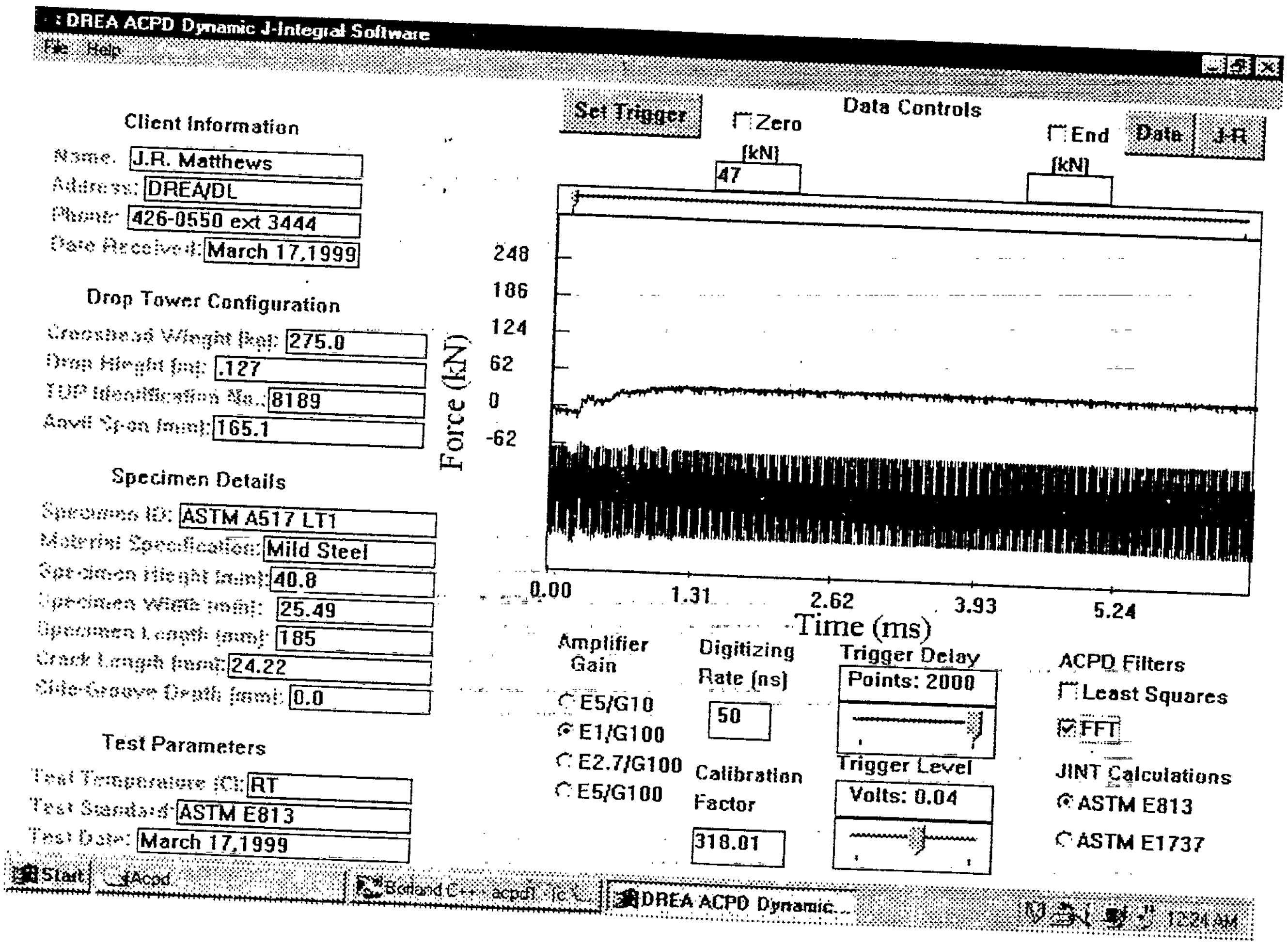
$$\frac{a}{W} = \left[0.2864\left(\frac{U}{U_0} - 0.5\right)\right]^{0.3506}$$

$$U_0 = \frac{U_B}{3.4916\left(\frac{a_o}{W}\right)^{2.851} + 0.5}$$

HARDWARE REQUIREMENTS



SOFTWARE INTERFACE

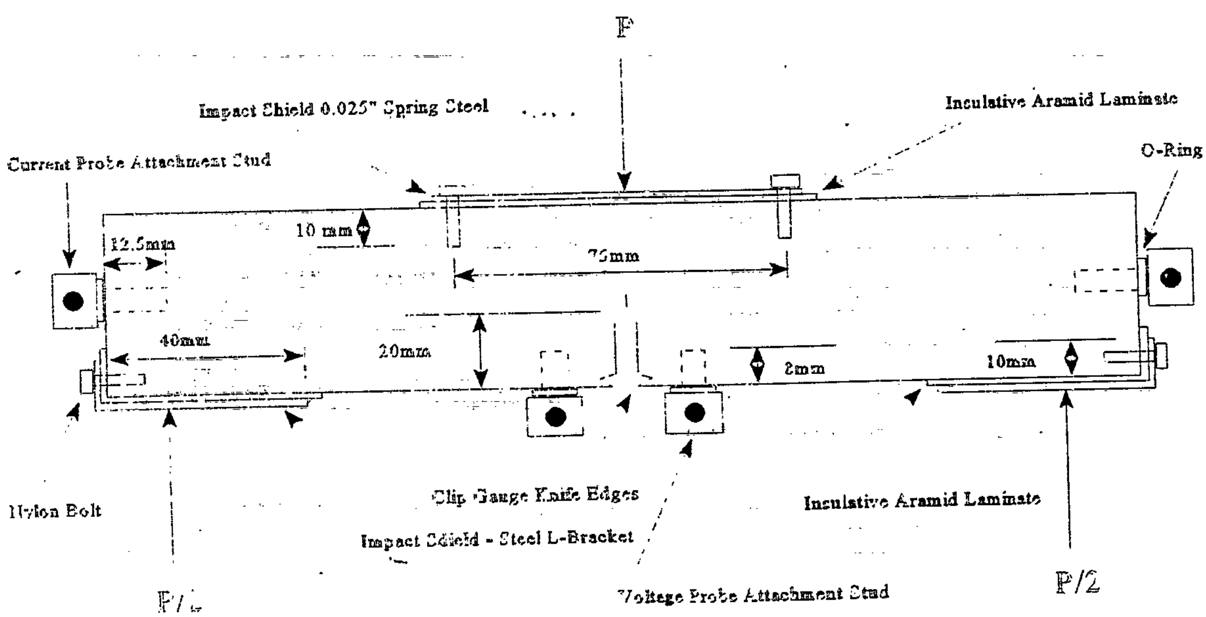


EXPERIMENTAL VERIFICATION

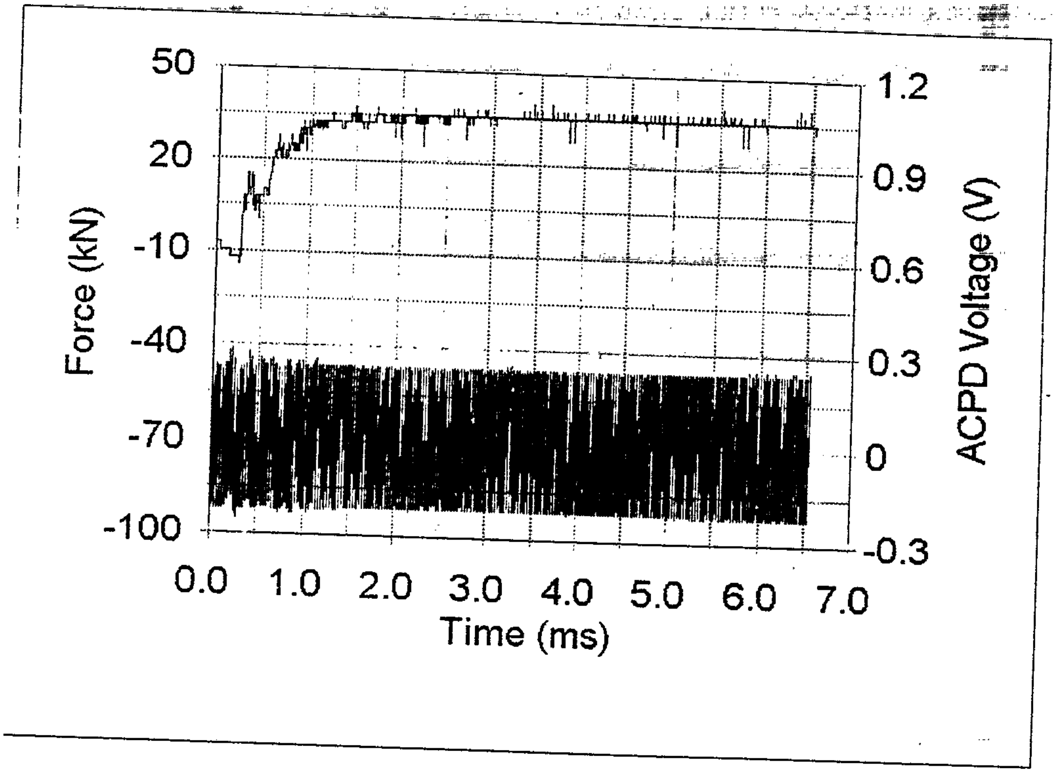
SPECIMEN PREPARATION

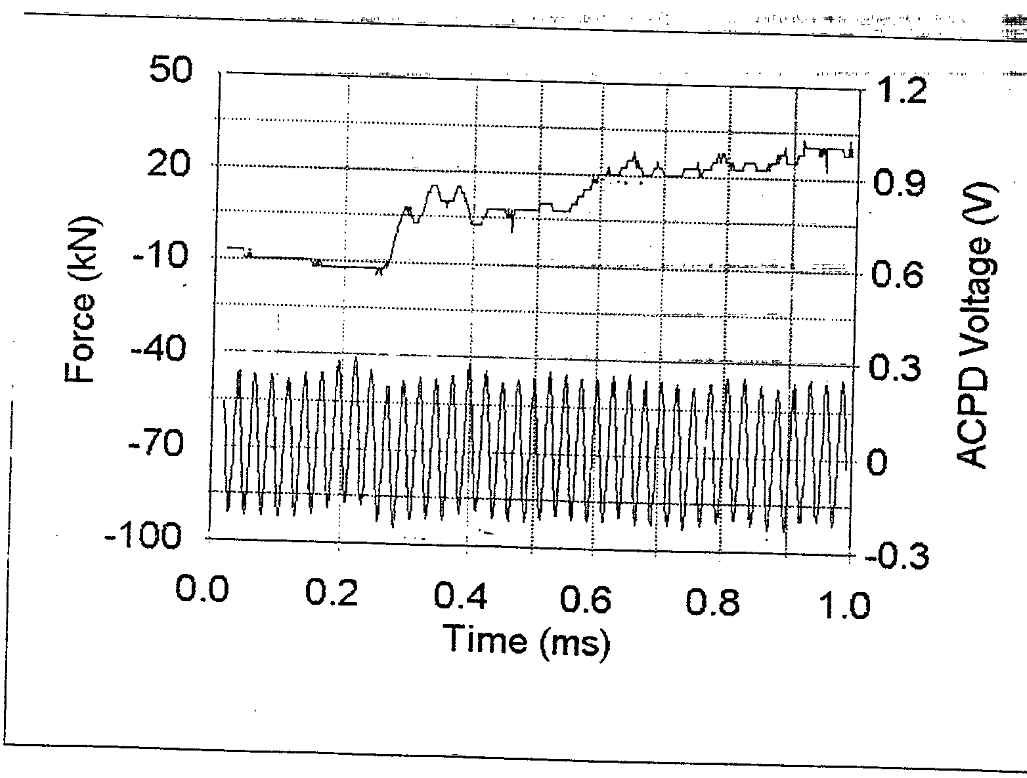
- MATERIAL - QUENCHED AND TEMPERED ALLOYED STEEL
- GEOMETRY - 25 mm x 50 mm x 181 mm
- NOTCH ORIENTATION L-T
- PRECOMPRESSED TO 0.4 PL AND PRECRACKED TO BETWEEN .45 AND .55 a/W
- TEST TEMPERATURE - AMBIENT
- SPECIMENS IMPACTED AT BETWEEN 1.4 m/s AND 1.7 m/s WITH A 275 kg CROSSHEAD (LOW BLOW TEST).
- AFTER TESTING SPECIMENS WERE HEAT TINTED AND INITIAL FATIGUE CRACK AND FINAL CRACK EXTENSION WERE MEASURED.

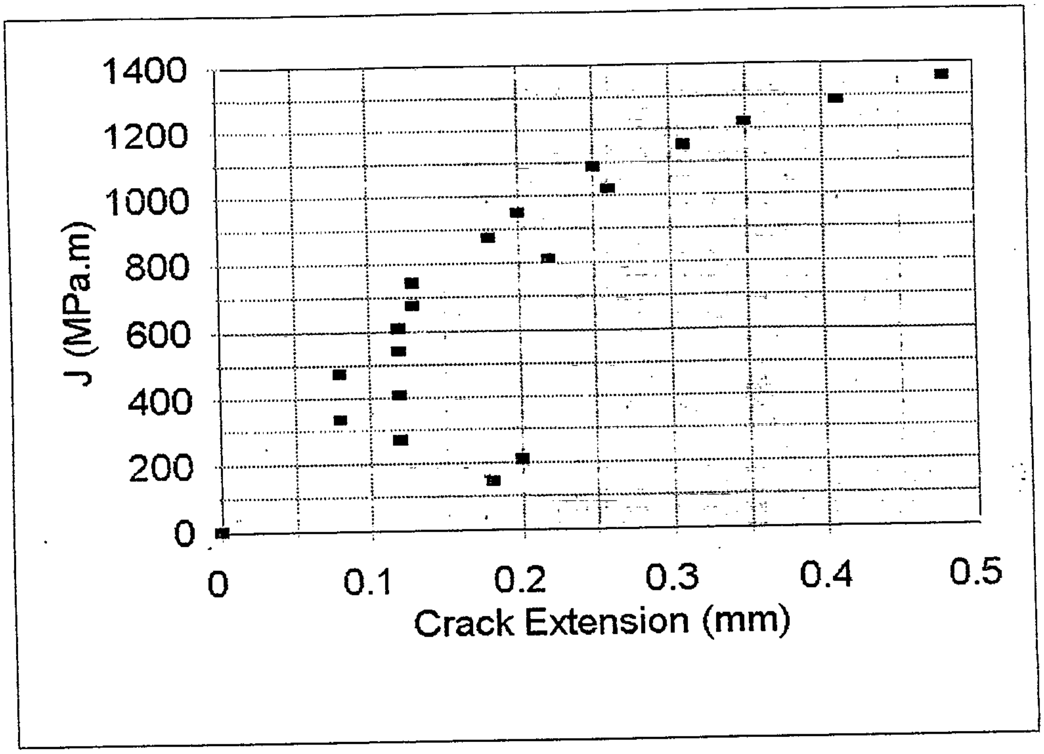
SPECIMEN PROBE ATTACHMENT POSITIONS



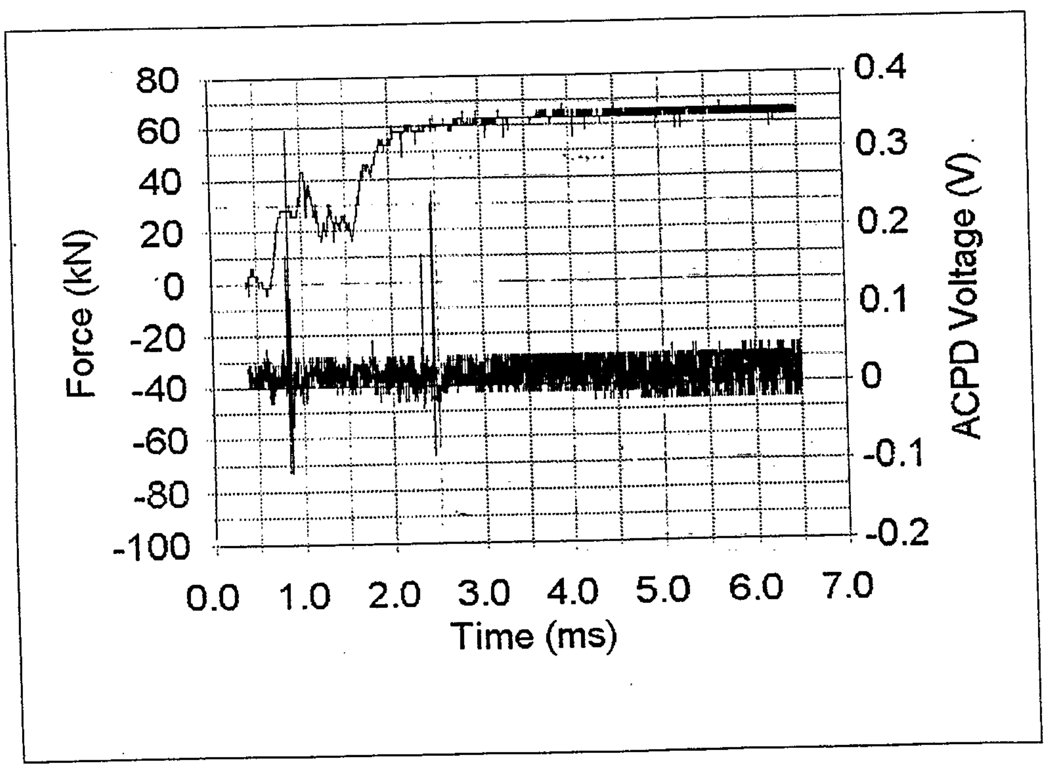
FORCE AND ACPD TEST DATA



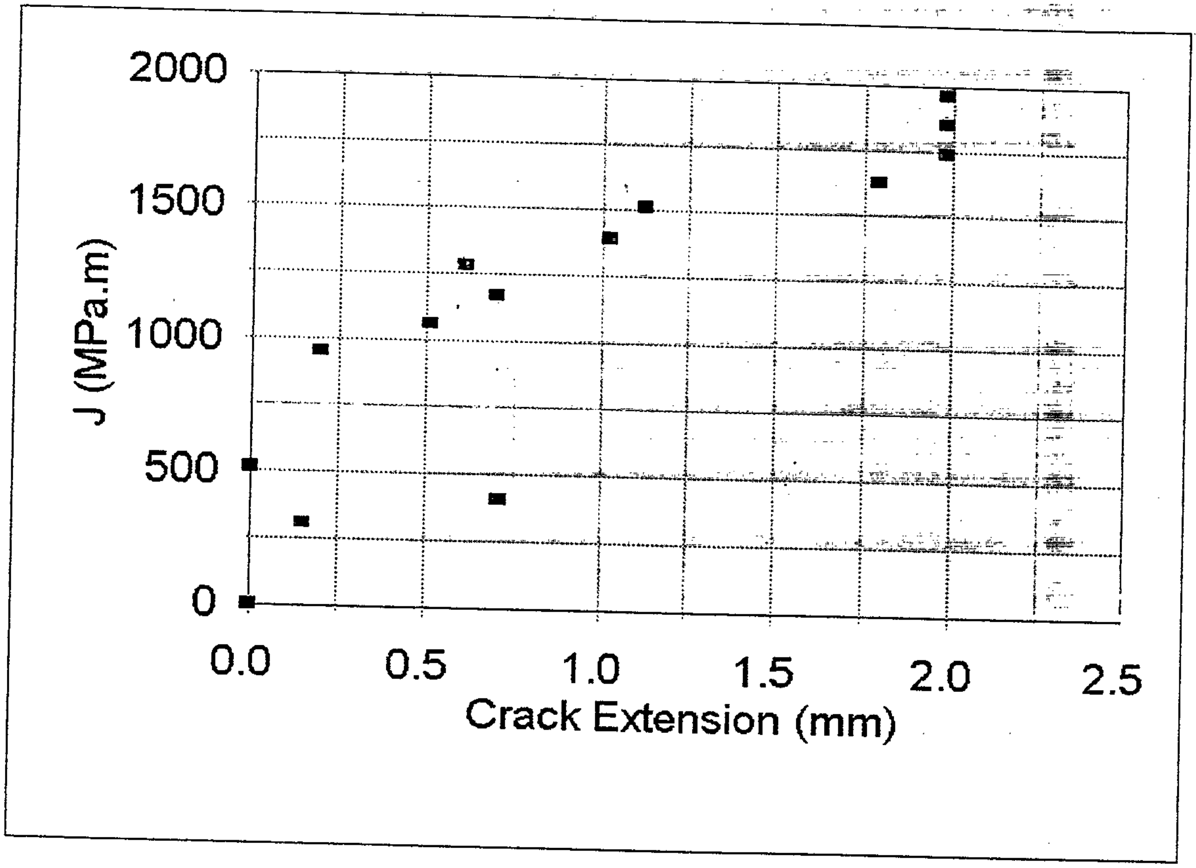




FORCE AND ACPD TEST DATA



J-RESISTANCE DATA



CONCLUSIONS

- THE EXPERIMENTALLY DERIVED EQUATION PUBLISHED IN ASTM E-1737 PROVIDES ACCEPTABLE ACCURACY FOR THE DETERMINATION OF CRACK EXTENSION FOR THE ACPD SYSTEM DEVELOPED. CALCULATED CRACK LENGTHS ARE IN CLOSE AGREEMENT WITH VISUALLY MEASURED CRACK LENGTHS.
- THE SPECIMEN INERTIAL EFFECTS GENERATE LOW FREQUENCY BACKGROUND NOISE INTO THE ACPD SIGNAL.
- SPECIMENS WHICH L OSE ELECTRICAL ISOLATION FROM THE LOAD TRAIN DURING THE IMPACT EVENT PRODUCE ACPD DATA WHICH GENERATES ERRONEOUS ESTIMATES OF CRACK LENGTH.